Evaluation of Grower Diets for Intensive Culture of Two Strains of Arctic Charr (*Salvelinus alpinus L.*)

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by

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ABSTRACT

Tabachek, J.L. 1984. Evaluation of grower diets for intensive culture of two strains of Arctic charr (Salvelinus alpinus L.). Can. Tech. Rep. Fish. Aquat. Sci. 1281: iv + 21 p.

In two experiments, Arctic charr and rainbow trout (Salmo gairdneri Richardson) from Sunndalsora, Norway and Arctic charr from Labrador, Canada were fed up to five trout and/or salmon diets. The control (CTR) diet appeared to be a suitable practical diet for use in determining the nutritional requirements of either strain of Arctic charr. Performance (weight gain and feed conversion) of Labrador charr was superior to that of Sunndalsora charr and was equivalent to or slightly better than rainbow trout fed the same diets [Martin Feed Mills GRT Trout Feed (MTT-GRT) and CTR]. In addition, performance of Labrador charr was also excellent with Martin Feed Mills MNR Trout Feed (MTT-MNR). Not all trout or salmon diets were suitable for production of both strains of Arctic charr. While MTT-GRT was an acceptable diet for both rainbow trout and Labrador charr, it was an unacceptable diet for Sunndalsora charr, as was the Abernathy salmon diet, while both Silver Cup Salmon and Trout Feeds were acceptable diets for Sunndalsora charr. Although the liver lipid content was elevated in both strains of charr fed MTT-GRT, CTR or MTT-MNR, it was not elevated in trout fed the same diets or Sunndalsora charr fed other diets. However, the muscle lipid contents of trout fed CTR or MTT-GRT tended to be slightly higher than charr fed the same diets and much higher than Sunndalsora charr fed other diets.

Adjustments for feed type should be included in a computerized fish data and management system developed to predict the growth of either strain of Arctic charr.

Key words: animal nutrition; aquaculture; rainbow trout; weight gain; food conversion; biochemical composition; commercial feed.

RESUME

Tabachek, J.L. 1984. Evaluation of grower diets for intensive culture of two strains of Arctic charr (Salvelinus alpinus L.). Can. Tech. Rep. Fish. Aquat. Sci. 1281: iv + 21 p.

Au cours de deux expériments, l'omble chevalier et la truite arc-en-ciel (Salmo gairdneri Richardson) de Sunndalsora, Norvège, et l'omble chevalier du Labrador, Canada, furent mis jusqu'à cinq sortes de régime alimentaire pour truite et/ou saumon. Le régime-témoin (CTR) paraissait être un régime pratique pouvant servir à déterminer les besoins en nutrition de l'une ou l'autre espèce d'omble chevalier. Les progrès constatés (gain de poids, indice de transformation) chez l'omble du Labrador étaient plus importants que ceux relevés chez l'omble de Sunndalsora, et ils étaient les mêmes, ou légèrement plus importants, que ceux constatés chez la truite arc-en-ciel à qui on avait fait suivre le même régime [Martin Feed Mills GRT Trout Feed (MTT-GRT) et CTR]. De plus, les progrès enregistrés chez l'omble du Labrador mis au régime de Martin Feed Mills MNR Trout Feed (MTT-MNR) étaient également excellents. Mais tous les régimes alimentaires pour truite ou omble ne convenaient pas aux deux espèces d'omble chevalier. Par exemple, le régime MTT-GRT convenait à la fois à la truite arc-en-ciel et à l'omble chevalier du Labrador, mais ne convenait pas à l'omble de Sunndalsora, et le régime Abernathy ne lui convenait pas non plus. Par ailleurs, les régimes Silver Cup Salmon et Trout Feeds lui convenaient. Quoique la teneur en lipides dans le foie était élevée chez les deux espèces d'omble mises aux régimes MTT-GRT, CTR ou MTT-MNR, elle ne l'était pas chez les truites qui y étaient soumises, ni chez l'omble de Sunndalsora soumis aux autres régimes. Toutefois, la teneur en lipides dans les muscles des truites nourries au régime CTR ou MTT-GRT avait tendance à être légèrement plus forte que celle des ombles soumis aux mêmes régimes, et sensiblement plus forte que l'omble de Sunndalsora soumis à d'autres régimes.

On doit tenir compte des diverses sortes de régime alimentaire auxquelles on soumet les espèces de poissons lorsqu'on prépare des données mécanographiques sur les poissons et qu'on met au point un système de gestion pour prédire la croissance de l'une ou l'autre espèce d'omble chevalier.

Mots-clés: alimentation des animaux; agriculture; truite arc-en-ciel; gain de poids; indice de transformation; composition biochimique; aliments commerciaux pour poissons.

INTRODUCTION

Recently, there has been an increasing interest in the culture of Arctic charr both in Europe (Gjedrem and Gunnes 1978; Wandsvik and Jobling 1982) and in Canada (Baker 1983; Papst and Hopky 1983). The effects of temperature (Uraiwan 1982; Wandsvik and Jobling 1982; Baker 1983; Jobling 1983), ration and size (Baker 1983; Jobling 1983; Jobling and Wandsvik 1983c), social interactions (Jobling and Wandsvik 1983a) and density (Baker, personal communication) on the growth of Arctic charr have been studied. However, the only research on the nutritional requirements of Arctic charr is the recent report from Norway by Jobling and Wandsvik (1983b). They stated that the protein requirements of Arctic charr were in the range of 35-45% which was almost identical to that of rainbow trout and that feeding Arctic charr diets formulated for rainbow trout should result in satisfactory growth rates. Evaluations have been conducted to assess the performance of rainbow trout (Tabachek 1983) fed different commercial feeds. This does not appear to have been done with Arctic charr. The effect of diet upon performance in rainbow trout (Tabachek 1983) was great enough to require inclusion of feed type into the model of Papst et al. (1982) and the computerized fish data and management system (FISHDAMS) of Arnason et al. (1981) being developed for an intensive production system utilizing waste heat (Papst and Hopky 1982, 1983).

The present studies were designed to evaluate the performance (weight gain, feed conversion, mortality) of a Sunndalsora (Norway) and a Labrador strain of Arctic charr fed up to 3 open (1-2 trout, 1 salmon and 1 control) and 2 closed (1 salmon and 1 trout) formulations. The purpose was to determine 1) which open formulation would be best to use in further research in diet formulation and nutritional requirements of Arctic charr, 2) if other commercially available trout or salmon feeds could be used to enhance the growth of Arctic charr raised in the hatchery and 3) if feed type would need to be included in a growth model developed to predict the growth of Arctic charr.

METHODS

FISH STOCKS

Experiment 1

Sunndalsora rainbow trout were progeny of a domestic strain obtained from a hatchery in Sunndalsora, Norway in April 1975 (Papst and Hopky 1983). Eggs for the present study were spawned in March 1981.

Sunndalsora Arctic charr were a second generation hatchery strain originating as an anadromous strain from northern Norway. They were received as eyed eggs December 15, 1980 from Sunndalsora Hatchery, Sunndalsora, Norway (Baker 1983).

Experiment 2

The Labrador Arctic charr were collected as eggs from an anadromous stock of fish from the Fraser River, Labrador in November 1981.

All trout and charr were incubated and reared at 6°C and were fed Sterling Silver Cup Trout Starter Feed and Martin Feed Mills Trout (GRT) Grower Feed.

DIETS

Experiment 1

Diets evaluated in Experiment 1 included two commercial trout diets [Martin Feed Mill Trout Feed (MTT-GRT) and Sterling Silver Cup Trout Feed (SCT)], one commercial salmon diet [Sterling Silver Cup Salmon Feed (SCS)], a salmon diet made to specifications for use in U.S. federal government hatcheries [Abernathy Salmon Production Diet (ABY)] and a control diet (CTR) (Table 1). Manufacturing dates and formulations of diets are presented in Tables 1 and 2 respectively. No other formulations could be evaluated due to a shortage of charr. The CTR diet was manufactured in the same way as described by Tabachek (1983) except that the feed mixture was extruded through a 2.4mm (3/32") die rather than a 3.3mm (1/8") die.

Undersized granules and fines were removed and collected from all feeds as previously described (Tabachek 1983). Screened feeds were sealed in bags and stored at -20°C. A sieve series separation was carried out on a sample of each prescreened sample of granular-size feed as outlined by Tabachek (1983). The diameter and length of the pellets was determined by direct measurement.

Moisture, ash and nitrogen contents were determined by AOAC (1980) methods for all prescreened feeds. Nitrogen was converted to crude protein by multiplication by 6.25. Total lipid was determined by a modified Bligh and Dyer (1959) extraction and spectrophotometric assay of the extract using acid dichromate oxidation (Fales 1971).

Experiment 2

In the spring of 1982, Martin Feed Mills ceased manufacturing GRT-G (MTT-GRT) as their grower diet and began manufacturing MNR-8204 (MTT-MNR) (Table 1) - the Ontario Ministry of Natural Resources formulation used in Ontario's provincial government hatcheries. The formulation of MTT-MNR is given in Table 2 and is very similar to the MNR (MNR-80G) diet evaluated for the production of rainbow trout (Tabachek 1983). The original lots of MTT-GRT and CTR from Experiment 1 were evaluated along with the new product (MTT-MNR) (Table 1) for the production of Labrador Arctic charr. Prescreening, sieve series and proximate analysis were conducted on MTT-MNR in the same manner as Experiment 1.

FEEDING TRIAL

Experiment 1

The feeding trial was conducted at the Rockwood Experimental Fish Hatchery located approximately 40 km north of Winnipeg, Manitoba (Ayles et al. 1981). Culture conditions were maintained as closely as possible with the previous experiment (Tabachek 1983) using a recirculation system, 60 L fiberglass tanks with a flow rate of 4-5 L/min and a water temperature of 12±1.0°C. Lighting was provided by yellow fluorescent bulbs giving light intensities of 0.69 and 0.48 microeinsteins $m^{-2}sec^{-1}$ for the upper and lower tanks respectively (Uraiwan 1982). Lighting was on a 12h light, 12h dark cycle. Water quality parameters (dissolved oxygen, pH, NH_4-N, NO_2-N and NO_3-N) were monitored biweekly as previously described (Stainton et al. 1974; Tabachek 1983) and temperature was monitored by a Weksler recorder.

The seven treatments (2 diets for Sunndalsora rainbow trout and 5 diets for Sunndalsora Arctic charr) were assigned at random within each of the four rows of tanks in a randomized complete block design. Acclimation was begun with 100-120 fish per tank. Two weeks prior to the experiment, fish were graded and grouped into lots by weight. Subsequently these lots were subdivided and transferred to tanks. Total weight of the 40 fish per tank varied from 510-528 g [517±1.2 (SE)] for charr and 514-526g (522±1.3) for trout when the experiment commenced. Total acclimation time was 4 weeks for trout and 7 weeks for charr.

The feeding regime was as described by Tabachek (1983) with fish being fed to satiation twice a day. Feeding was done carefully in a manner that minimized feed loss. Feed size was changed when fish accepted the larger size. Total feed intake per tank was measured weekly by weighing feed at the beginning and end of each weekly period. Total weight and number of fish per tank were determined biweekly. Mortalities were removed and recorded daily.

After 14 weeks, the rainbow trout had achieved a density of 54 kg/m^3 and the trout phase of the experiment was terminated. Fish were anaesthetized with 2-phenoxyethanol. Whole body weight and liver weight were measured for each of 6 fish per tank. Liver and muscle (skin and bone removed) samples were taken for analysis from these 6 fish as 3 samples of 2 fish each. Blood haematocrits were measured according to Wedemeyer and Yasutake (1977) from blood samples collected from the caudal peduncle of 6 fish per tank and centrifuged in an Adams Autocrit.

The Arctic charr phase of Experiment 1 was terminated at 20 weeks when the density of fish fed some diets exceeded 50 kg/m^3. These samples were processed in the same manner as the rainbow trout.

Experiment 2

Culture conditions were the same as in Experiment 1 except that only one lower row of tanks was used. The three diet treatments were assigned at random in a completely randomized design with three replicates per diet. Labrador Arctic charr were graded by weight in a similar manner as Experiment 1 and were acclimated to their new environment for a total of 3 weeks. Total weight of the 40 fish per tank varied from 484-497g (490±1.6) when the experiment commenced. Feeding regime and sampling schedules were the same as for Experiment 1. Water quality parameters were measured weekly. When the experiment was terminated at 12 weeks, sampling procedures were carried out in the same manner as in Experiment 1.

HISTOLOGY AND GROSS EXAMINATION

At the termination of both Experiment 1 and 2, all fish were visually examined for the presence of lens cataracts. A sample of 6 fish were examined and the condition of the kidney, liver, and skin colouration was noted. Amount of visceral fat was quantified by giving it a value of 0 for none, 1 for light, 2 for medium and 3 for high accumulation of fat. Samples of kidney, heart, spleen and thyroid were taken from 2 fish per tank, fixed in Bouin's solution and treated for histological examination as described by Tabachek (1983).

BIOCHEMICAL ANALYSIS OF MUSCLE AND LIVER

In both Experiment 1 and 2, moisture, total lipid and crude protein contents were determined on muscle and liver samples as described by Tabachek (1983). Since body composition is related to fish size (Reinitz 1983), an attempt was made to raise fish to similar final body weights.

STATISTICAL ANALYSIS

When Bartlett's test of homogeneity of variance (Steel and Torrie 1980) was applied to performance and biochemical data, variances for hematocrit, hepatosomatic indices, and biochemical composition of liver and muscle were found to be non-homogeneous in Experiment 1. Square root transformation (Steel and Torrie 1980) was applied to these data to equalize variances. In both Experiments 1 and 2, this transformation was also applied to percent mortality data. All data, in either the appropriate transformed or non-transformed state, were subjected to analysis of variance and Duncan's new multiple range test (Duncan 1955) using the Statistical Analysis System (SAS Institute 1979). Data are presented in the non-transformed state. Linear regression was used to determine $\log_e$ (ln) weight vs time relationships for each treatment for comparison with the work of Uraiwan (1982), Baker (1983) and Papst and Hopky (1983).

RESULTS

DIETS

Formulation

Within each of CTR, MTT-GRT and MTT-MNR, the same formulation was used for all sizes of feeds obtained (Tables 1 and 2), while ABY had a different formulation for the granular vs pelleted feeds. SCS and SCT feeds were closed formulations whose quantitative ingredients were known only by the manufacturer.

Proximate composition of diets

Proximate composition of diets (Table 3) showed that crude protein was 41-45% for CTR and MTT-GRT and 47-53% for all other diets. Total lipid ranged from a low of 9-11% for SCT to a high of 15-17 for CTR and MTT-MNR while ABY contained 12-14% lipid. Both SCS and MTT-GRT were variable in lipid content between the granular and pelleted feeds with 10.5 and 14.7% for SCS and 14.2 and 17.2% (21% in Experiment 2) for MTT-GRT. Ash was less than 10% for CTR, MTT-GRT and MTT-MNR while it was 10-12.5% for the other diets.

Sizes of diets

The "fines" removed constituted up to 2.6% and 1.6% of the granular and pelleted feeds respectively (Table 4). These were less than previously reported (Tabachek 1983) and probably would have made little difference to feed conversion if they had not been removed. The screen series (Table 4) showed the relative percentage of particle sizes present in the granular size was similar for CTR, MTT-GRT and MTT-MNR which were smaller than ABY, SCS and SCT. The SCS and SCT diets were similar although slightly larger than ABY. Mean pellet length was similar in Experiment 1 ranging from 4.3-4.5mm, except for SCS which was 4.9mm long. In Experiment 2, mean pellet length varied considerably from 3.7-4.5mm for the three diets.

Feed sizes were changed when fish accepted the larger size. This occurred after 6 weeks for rainbow trout and 10 weeks for Sunndalsora Arctic charr in Experiment 1. After 2 weeks, the fish fed ABY had gained only 1.4g compared to 4.3 g the previous two weeks. Since this appeared to be related to a change of particle size, they were continued on the granular feed for two more weeks before changing to the pellets again. The entire 10-14 week period was used as the apparent increase in the weight (Fig. 1) for charr fed ABY at 12 weeks. These fish were raised for an additional 2 weeks (until 22 weeks) to compensate for the low gain 2 week period. In Experiment 2, feed size was changed after 8 weeks.

PERFORMANCE

Experiment 1

At the termination of the rainbow trout phase of Experiment 1 (14 weeks), trout fed CTR or MTT-GRT had gained significantly more than Sunndalsora charr fed the same diets (Table 5). Although there were no significant differences in performance between trout fed either diet, charr fed MTT-GRT gained significantly less than those fed the CTR diet. In addition, feed conversion was significantly poorer for charr fed MTT-GRT (2.60) than for trout or charr fed either diet (1.11-1.41).

By 8 and 12 weeks, weight gain and feed conversion, respectively, were significantly better for charr fed CTR compared to either ABY or MTT-GRT and this continued to the end of the experiment (Table 6). Performance was similar for charr fed SCS and SCT and was neither significantly poorer than CTR nor significantly better than MTT-GRT. Performance parameters were poorest for Sunndalsora charr fed ABY. Mortality was less than 10% with no significant difference between diets. The slopes of the regression lines (Tables 5 and 6), which are a measure of growth rate over the specific time period, also reflect the above effects of diet.

Experiment 2

There were no significant differences in weight gain or feed conversion between Labrador Arctic charr fed the three diets (Table 7). Slopes of the regression lines also show little difference in growth rate. Mortality was very low in fish fed all diets.

HAEMATOCRIT VALUES AND BIOCHEMICAL COMPOSITION OF MUSCLE AND LIVER

Experiment 1

The hepatosomatic indices (HSI) (Table 8) were significantly greater for Sunndalsora charr fed a) CTR or MTT-GRT compared to trout fed the same diets or b) MTT-GRT compared to charr fed all other diets. In addition, liver lipid was significantly higher while liver moisture was significantly lower for charr fed CTR or MTT-GRT compared to charr or trout fed all diets.

In contrast to the liver, the muscle of charr fed MTT-GRT contained significantly less lipid and more protein than trout fed the same diet. This was also true of the muscle lipid (% dry) and protein (% wet) contents of CTR-fed charr vs trout. The muscle tissue of fish fed ABY was higher in moisture and lower in lipid than fish fed any other diet. Muscle composition of SCS and SCT-fed charr differed only in protein content (% wet) while there was no difference in liver composition.

Charr fed ABY or CTR had significantly lower blood haemotocrit values than fish fed any other diet.

Experiment 2

No significant differences were apparent in HSI, blood haemotocrit value, liver or muscle moisture, lipid or protein contents in Labrador charr fed the three diets (Table 9).

HISTOLOGY AND GROSS EXAMINATION

Lens cataracts were observed in less than 1% of the rainbow trout and 7-11% of the Sunndalsora Arctic charr in Experiment 1. They were less prevalent in Labrador charr (1-2%) in Experiment 2. In neither experiment did they appear to be attributable to any particular diet. In both Experiment 1 and 2, skin and fins on the ventral side of charr fed MTT-GRT or MTT-MNR had a bright yellow colouration which was not evident in trout or charr fed any other diets. No gross abnormalities were observed that could be attributed to diet. Histological examination revealed no abnormalities in kidney, thyroid, or spleen in Sunndalsora charr or trout in Experiment 1. There were no significant differences in the amount of visceral fat (Tables 8 and 9) between fish fed any diets in Experiment 1 or 2.

WATER QUALITY

Water quality parameters monitored throughout Experiments 1 and 2 are presented in Table 10. Ammonia-N (NH_4+NH_3-N) increased throughout the experiments reaching concentrations greater than 300 µg/L during the last 2-4 weeks. Nitrite-N (NO_2-N) generally ranged from 2-6 µg/L (Experiment 1) and 10-34 µg/L (Experiment 2). High levels (75-79 µg/L) were observed only at 12 weeks (Experiment 1) and 0 week (Experiment 2) and dropped thereafter.

DISCUSSION

The purpose of this experiment was to evaluate available trout and salmon diets, especially open-formula diets, to find a practical diet that could be used in further experiments for determining the nutritional requirements of Arctic charr. Superior diets may be developed in the future but the CTR (C-201) formulation appears to be a suitable practical diet for such experiments with both strains of Arctic charr. MTT-MNR, which is similar to CTR, is definitely suitable for research with Labrador charr and should be evaluated for use with Sunndalsora charr. Both MTT-GRT and ABY were unacceptable as diets for Sunndalsora charr. Performance of Sunndalsora charr was satisfactory with either closed trout or salmon formulations (SCT and SCS). Jobling and Wandsvik (1983b) stated that rainbow trout diets could be expected to result in satisfactory rates of growth when fed to Arctic charr. However, it would appear from the present study that not all rainbow trout or salmon diets are suitable for raising all strains of Arctic charr.

The growth rate of Labrador Arctic charr (slope = 0.020-0.021, r^2>0.98) (Experiment 2) was higher than that of Sunndalsora charr (slope = 0.010-0.014, r^2=0.89-0.98) or rainbow trout (slope = 0.018, r^2>0.96) (Experiment 1) fed CTR or MTT-GRT. The regression equations representing the growth of Sunndalsora rainbow trout [(Y=2.70+0.018X; Y=weight(g), X=time(days)] and Labrador Arctic charr (Y=2.52+0.020X) fed MTT-GRT were similar to those of Papst and Hopky (1983) (Y=2.68+0.019X and Y=2.75+0.019X, respectively) for the same strains and diet. The initial weight and time period was approximately the same as in this study although their fish were raised in a large pilot-scale commercial system at a slightly higher water temperature (13.3 ± 0.06°C). The results for Labrador charr were also similar to the specific growth rate (2.17% day^{-1}) for 8-9 g Arctic charr from Nauyak Lake, NWT fed SCT at maximum ration in the same culture system at 13°C (Uraiwan 1982).

In comparison of Labrador and Sunndalsora charr fed the same diets, it should be kept in mind that the experiments were conducted at different times. Although every effort was made to keep conditions the same, there were some differences in water chemistry. The loading rate on the filters was different with 14 tanks per filter in Experiment 1 and 9 tanks per filter in Experiment 2. Although the asymptotic LC50 for 12g rainbow trout is 140-150 µg/L NO_2-N (Russo et al. 1974), fish are stressed at levels much lower than this. The high levels of NO_2-N (75-79 µg/L) at 12 weeks during Experiment 1 and during the first 2 weeks of Experiment 2 probably caused stress. Therefore, under ideal conditions the growth rates might have been better at these times. In both experiments, unionized ammonia levels were within the limits set by Liao and Mayo (1972) and dissolved oxygen and pH met the requirements for fish culture (Wedemeyer and Wood 1974).

A possible explanation of the differences in performance between charr fed different diets may be due to differences in the dietary levels of protein and lipid. Jobling and Wandsvik (1983b) concluded that the optimum protein requirement for their strain of Norwegian Arctic charr was 35-45% at 15 and 11% lipid respectively. However, experiments in progress have indicated that the protein and lipid requirements of 3-40 g charr originating from Nauyuk Lake, NWT, are higher than this and are about 44-54% protein with 15-20% lipid. Dietary lipid can have a sparing effect on protein (Takeuchi et al. 1978; Watanabe 1977) allowing utilization of protein for growth rather than for energy. Therefore, although ABY, SCS and SCT contained 47-53% protein, their lipid contents were generally 9-14%, a level which may not have allowed optimization of the protein available. These less than optimal lipid levels may have contributed to the poorer growth and feed conversion of ABY, SCS and SCT compared to CTR. Although feed conversion of both strains of charr fed most diets decreased gradually throughout the experiment, it increased for Sunndalsora charr fed MTT-GRT until 10-12 weeks and then decreased thereafter. This resulted in an overall feed conversion of 2.60 at 14 weeks and 2.19 at 20 weeks. At 10 weeks, the pelleted feed replaced the granular feed resulting in a decrease in dietary protein and an increase in dietary lipid. This may have resulted in an energy-protein ratio that allowed for more optimal utilization of the available nutrients.

Sunndalsora charr fed MTT-GRT or CTR had a significantly higher hepatosomatic index (HSI) than those fed other diets. This enlargement appears to be due to storage of lipid - almost 10-23% more than trout fed the same diets or charr fed other diets in Experiment 1, while the same diets fed to Labrador charr resulted in similar high levels of liver lipid deposition. This may be related to CTR, MTT-GRT and MTT-MNR's having an inadequate level of protein for the amount of lipid provided. ABY, SCS and SCT, which may have had insufficient dietary lipid, resulted in charr with lower liver lipid contents similar to those of rainbow trout. However, the muscle lipid contents of trout fed CTR or MTT-GRT tended to be slightly higher than charr fed the same diets and much higher than Sunndalsora charr fed other diets. Buckley and Groves (1979) summarized the influence of diet on body composition of several species of fish and related the facts that percent body fat has been correlated with dietary fat and energy levels, while dietary protein levels had no significant influence on either percent carcass fat or protein in rainbow trout. Although, dietary lipid may have had an influence on muscle lipid contents, differences in both dietary lipid and protein within (granular vs pelleted feeds) and between diets make this impossible to assess for this experiment.

Baker (1983) found that the growth rate of Labrador charr exceeded that of the Sunndalsora (Norway) charr when the two strains were fed SCT (initial weight=10g and 24g) or MTT-GRT (initial weight=60g) at 14°C. He found that the Sunndalsora charr had a higher mean maintenance ration requirement than Labrador charr, particularly at 14-19°C, suggesting a higher maintenance metabolism. Sunndalsora charr required greater amounts of food to achieve maximum and optimum growth rates and had poorer feed conversion than the Labrador charr. In the present study, Labrador charr utilized both CTR and MTT-GRT efficiently (1.15 and 1.17, respectively) while Sunndalsora charr utilized CTR (1.35) significantly better than MTT-GRT (2.19).

There are clearly differences in either the nutritional requirements, nutritional tolerance to dietary ingredients or digestibility of certain ingredients between strains of Arctic charr. Such differences have also been found between families of rainbow trout in terms of protein digestibility, protein (Austreng and Refstie 1979) and carbohydrate (Refstie and Austreng 1981) requirements.

Comparison of the ingredients in the open-formula diets revealed the following information. In comparing the formulation of CTR and MTT-GRT: 1) corn gluten meal in MTT-GRT replaced some soybean meal, 2) feather meal and poultry by-product meals replaced some fish meal, 3) brewers' dry yeast replaced some wheat middlings in the CTR diet, and 4) calcium phosphate was added to MTT-GRT. In addition, MTT-GRT's vitamin supplement contained considerably less vitamin D_3 and more vitamin A and antioxidants than CTR. Collectively, these differences resulted in a significant reduction in weight gain and an increase in feed conversion when MTT-GRT was fed to Sunndalsora charr. There were few differences between the major ingredients in MTT-GRT and MTT-MNR. In the latter, poultry by-product meal and calcium phosphate were eliminated, whey replaced a portion of the wheat middlings, and the vitamin supplement contained 8 times more vitamin D_3 and up to 1.5 times more other vitamins than MTT-GRT. These changes resulted in a minor improvement in the performance of Labrador charr fed MTT-MNR.

Performance of Sunndalsora charr was poorest when they were fed ABY or MTT-GRT. This may be related to dietary levels of vitamin D_3 and/or calcium. Both diets were supplemented with very low levels of vitamin D_3 (440 and 560 IU/kg diet, respectively) compared to CTR or MTT-MNR (2000 and 4500 IU/kg diet, respectively). Recommended levels for fingerling trout are 1600-2400 IU vitamin D_3/kg diet (NRC 1981). In addition, both diets were higher in calcium, through addition of calcium phosphate (MTT-GRT) or additional fish and shrimp meals (ABY), as opposed to CTR and MTT-MNR. The influence of these factors on performance should be investigated in future.

Since fish with a high fat content have a shorter storage life than lean fish due to the susceptibility of unsaturated fatty acids to oxidation (Hobbs 1982), the charr should have an equivalent or longer storage life than rainbow trout. An aesthetic difference which should appeal to the consumer was the fact that the fins and skin on the ventral side of charr fed MTT-MNR or MTT-GRT had a bright yellow colouration. This was probably due to carotenoids present in the corn gluten meal used as an ingredient in these diets. Corn gluten meal contains high levels of xanthophyll (72.36 mg/kg dry) (NRC and Dep. of Agric. 1971) and caused a yellow pigmentation in brook trout (Salvelinus fontinalis) (Tunison et al. 1947) when incorporated into their diet.

Adjustments for feed type used in the production of Arctic charr should be included in a computerized fish data and management system (FISHDAMS) such as the one developed for production of rainbow trout (Arnason et al. 1981). It would require 3-3.5 more weeks for MTT-GRT and 5-5.5 more weeks for ABY-fed Sunndalsora charr to reach the same mean weight as SCS and SCT-fed fish and a further 1.5-2 weeks to reach the same final mean weight as CTR-fed charr. In raising Labrador charr, 1.5-2 more weeks would have been required for fish fed MTT-GRT to reach the same weight as those fed CTR and MTT-MNR. These differences would have been magnified if the charr had been raised closer to market size as in the study by Tabachek (1983). In that study, performance of rainbow trout was similar with SCT, MTT-GRT and MTT-MNR and would not have required changes in FISHDAMS, while performance was superior with CTR and inferior with several other diets necessitating changes in the model.

New information regarding nutritional requirements of fish, as well as availability and cost of ingredients can create the need for changes in formulation. This may result in variability in performance and body composition,

even in using feed from the same manufacturer. The extent of this variability could only be determined by conducting similar evaluations over a period of time.

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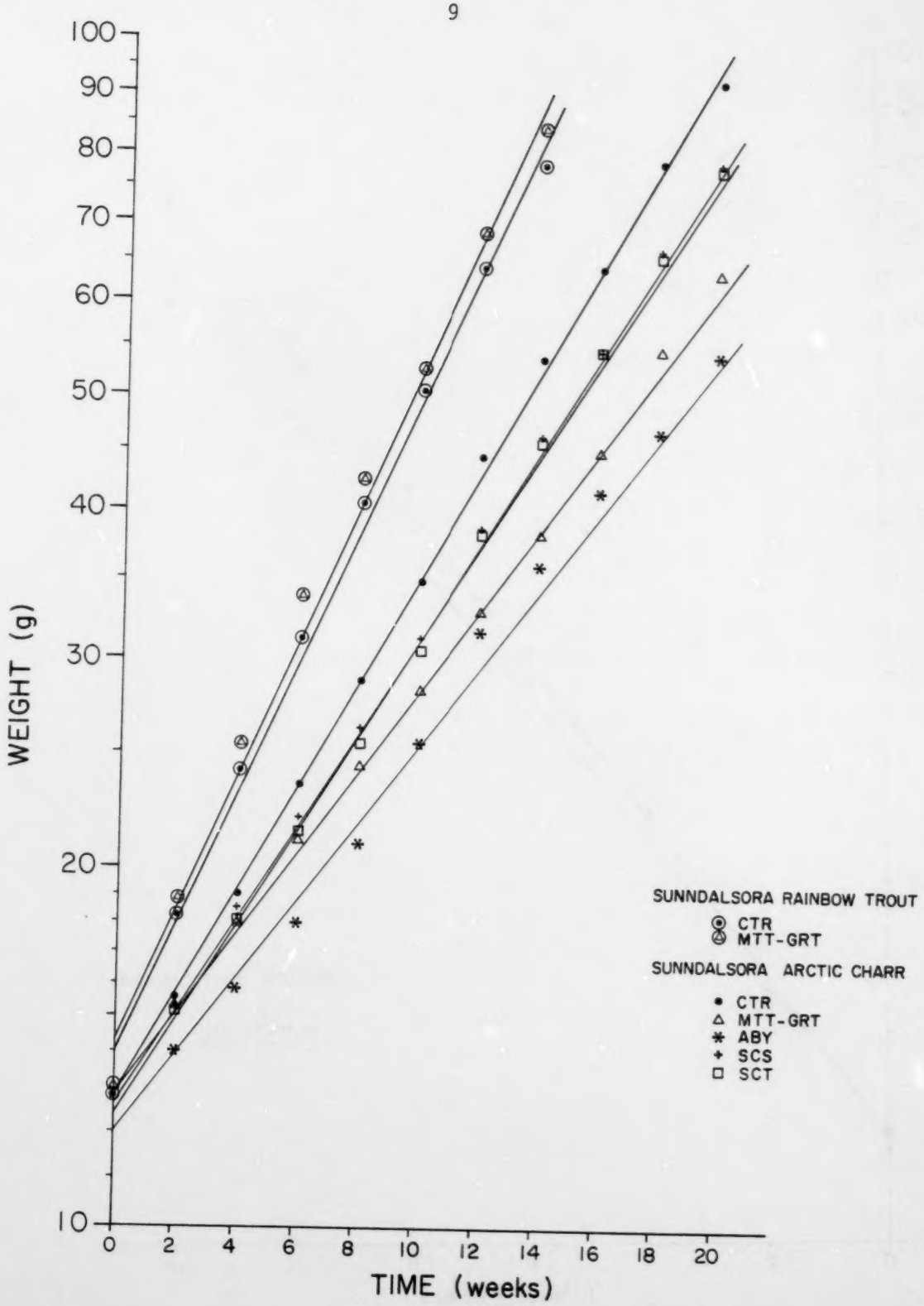

Figure 1. Changes in mean fish weight for Sunndalsora Arctic charr and rainbow trout for 20 and 14 weeks respectively (Experiment 1).

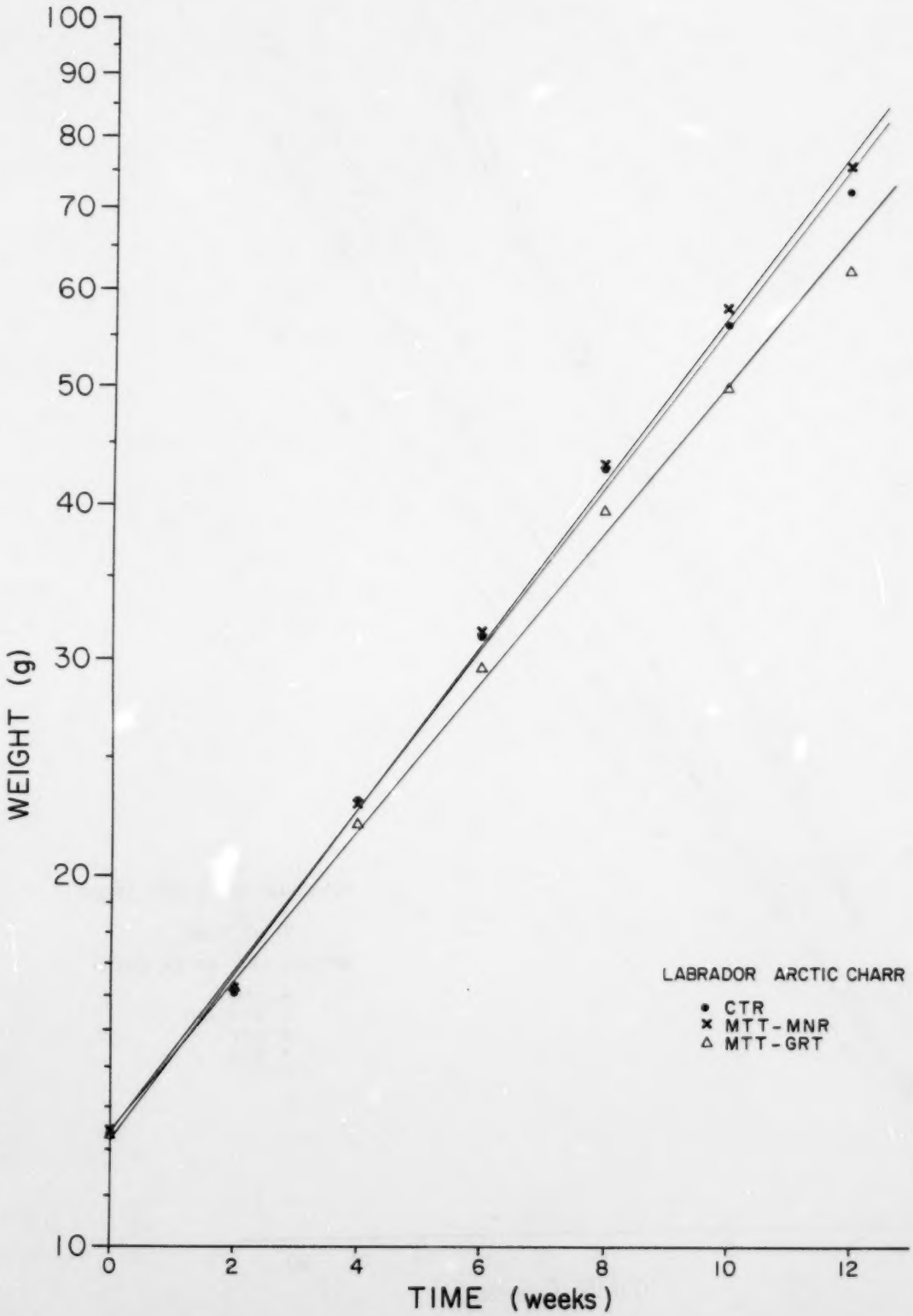

Figure 2. Changes in mean fish weight for Labrador Arctic charr for 12 weeks (Experiment 2).

Table 1. List of diets evaluated, their codes, manufacturer, size and date of manufacture.

Experiment	Diet	Code	Formulation (See Table 2)	Manufacturer	Size[3]	Date of manufacture
1 & 2	Control	CTR	C-201[1]	Author Winnipeg, Man.	# 4	20-29/01/82
					2.4mm(3/32")	29/01/82
1 & 2	Martin Feed Mill Trout Feed	MTT-GRT	GRT-G	Martin Feed Mills Elmira, Ont.	# 4	24/12/81
					3mm	22/12/81
					3mm	24/03/82
1	Abernathy Salmon Production Diet	ABY	A18-1(81) A19-1(81)	Rangen Inc. Buhl, Idaho	6/64"granules 3/32"	19/01/82 01/82
1	Sterling Silver Cup Salmon Feed	SCS		Murray Elevators Murray, Utah	# 4	14/01/82
					3/32"	14/01/82
1	Sterling Silver Cup Trout Feed	SCT		Murray Elevators	# 4	26/02/82
					3/32"	16/01/82
2	Martin Feed Mill Trout Feed	MTT-MNR	MNR-8204[2]	Martin Feed Mills Elmira, Ont.	2GR	26/10/82
					3PT	29/09/82

[1]University of Guelph, Ontario formulation
[2]Ministry of Natural Resources, Ontario formulation
[3]Manufacturer's numbering system for size of granules and pellets

Table 2. Formulation (%) of the diets.[1]

Ingredient	CTR C-201	MTT-GRT GRT-G	MTT-MNR MNR-82G (Experiment 2)	ABY A18-1(81)	ABY A19-1(81)
Fish meal	35.0[2]	24.0[3]	27.0[4]	48[5]	45[5]
Feather meal, hydrolyzed (80-82% crude protein (CP)[6]	-	5.0	8.0	-	-
Poultry by-product meal (60% CP)	-	7.0	-	-	-
Shrimp meal, dried (38% CP)	-	-	-	5	5
Blood flour, dried or blood meal, ring-dried (80% CP)	-	-	-	5	5
Soybean meal (48% CP)	20.0	10.0	10.0	-	-
Corn gluten meal (60% CP)	-	9.0	10.0	-	-
Wheat middlings (17% CP, 8% fiber)	32.4	28.3	21.3	-	-
Wheat middlings, wheat mill run or wheat shorts (15% CP, max fiber 9.5%)	-	-	-	0-15	0-17
Brewer's dried yeast (35-45% CP)	-	5.0	5.0	5	5
Whey, spray-dried (12% CP)	-	-	7.0	-	-
Whey, dried or dried whey product (12% CP, max ash 10%) or wheat clears (12% CP)	-	-	-	10	10
Fish oil, stabilized	10.0[7]	8.0[8]	9.0[9]	-	-
Fish oil, stabilized or soybean lecithin: fish oil (50:50)	-	-	-	5	5
DL-methionine	0.2	0.2	0.2	-	-
Choline chloride (50%)	0.4	0.8	-	-	-
(70%)	-	-	-	0.5	0.5
Vitamin premix	1.0[10]	-	1.5[11]	1.5[12]	1.5[12]
Vitamin + mineral premix	-	1.0[13]	-	-	-
Mineral premix	1.0[14]	-	1.0[15]	0.1[16]	0.1[16]
Iodized salt	-	0.3	-	-	-
Calcium phosphate (21.0% Ca)	-	1.4	-	-	-
Ascorbic acid	-	-	-	0.089	0.089

-Ingredient not added to diet.

[1]SCS contained animal protein products, plant protein products, processed grain by-products, lecithin, fish oil, soybean oil, lignin sulfonate, salt, Vitamin A acetate, D-activated animal sterol (D_3), Vitamin B_{12} supplement, riboflavin, niacin, folic acid, menadione sodium-bisulfide, pantothenic acid, pyridoxine, thiamine, biotin, DL-α-tocopherol, ascorbic acid, choline chloride, cobalt sulphate, copper carbonate, ferric oxide, manganous oxide, BHT, added mineral matter (not more than 2.50%).

SCT contained fish meal, soybean meal, wheat middlings, brewer's dried grains, brewer's dried yeast, dehydrated alfalfa meal, corn fermentation solubles, dried whey, blood meal, hydrolyzed feather meal, wheat germ meal, degossypolized cottonseed meal and meat meal (3/32" feeds), lecithin, soybean oil, lignin sulfonate, ferrous carbonate, ethylene-diamine-dihydroiodide and all the other minerals and vitamins listed in SCS as above.

[2]Herring meal, 68% CP (crude protein).

[3]Capelin meal, 70% CP.

[4]Herring or capelin meal, 68% CP, 13% ash.

[5]Herring (67.5% CP) or anchovy (65% CP) meal.

[6]CP values represent minimum requirements.

[7]Capelin oil.

[8]Herring oil.

[9]Herring, capelin or salmon oil with 6% of this sprayed on pellets or granules.

[10]Vitamin premix (VIT-8004), in a wheat middling carrier, supplied in milligrams per kilogram of diet (except as noted): vitamin A acetate, 5000 IU; vitamin D_3, 2000 IU; dl-alphatocopheryl acetate, 200 IU; menadione sodium bisulfite 30; thiamine HCl, 30; riboflavin, 50; d-Ca-pantothenate, 150; biotin, 0.4; folic acid, 10; vitamin B_{12}, 0.03; niacin, 200; pyridoxine HCl, 30; ascorbic acid, 300.

[11]Vitamin premix (VIT-8204), in a wheat middling carrier, supplied in milligrams per kilogram of diet (except as noted): vitamin A acetate, 7500 IU; vitamin D_3, 4500 IU; dl-alphatocopheryl acetate, 150 IU; menadione sodium bisulfite, 45; thiamine HCl, 45; riboflavin, 75; d-Ca-pantothenate, 225; biotin, 0.75; folic acid, 15; vitamin B_{12}, 0.045; niacin, 300; pyridoxine HCl, 45; ascorbic acid, 600; choline chloride, 4500.

[12]Vitamin premix (No. 1) in a wheat by-product base, supplied in milligrams per kilogram of diet (except as noted): vitamin A acetate or palmitate, 6593 IU; vitamin D_3, 440 IU; alphatocopheryl acetate, 500 IU; vitamin K, 33; thiamine, 43; riboflavin, 53; d-pantothenic acid, 229; biotin, 0.06; folic acid, 13; vitamin B_{12}, 0.06; niacin, 220; pyridoxine HCl, 37.

[13]Vitamin-mineral premix (1-79), in a corn shot carrier, supplied in milligrams per kilogram of diet (except as noted): vitamin A, 8000 IU; vitamin D_3, 560 IU; vitamin E, 748 IU; menadione, 28; thiamine, 51; riboflavin, 40; calcium pantothenate, 150; biotin, 1; folic acid, 10; vitamin B_{12}, 0.03; niacin, 252; pyridoxine, 31; ascorbic acid, 402; ethoxyquin, 500; I (as KI), 7.5; Mn (as $MnSO_4.H_2O$), 87; Fe (as $FeSO_4.7H_2O$), 60; Cu (as $CuSO_4.5H_2O$), 25; Zn (as $ZnSO_4.H_2O$), 144.

[14]Mineral premix (MIN-8004), in a wheat middling carrier, supplied in milligrams per kilogram of diet: I (as KI), 7.5; Mn (as $MnSO_4.H_2O$), 87; Fe (as $FeSO_4.7H_2O$), 86; Cu (as $CuSO_4.5H_2O$), 25; Zn (as $ZnSO_4.H_2O$), 144; NaCC, 3000.

[15]Mineral premix (MIN-8204): same as MIN-8004.

[16]Mineral premix, in an inert carrier, supplied in milligrams per kilogram of diet: I (as KIO_3), 0.5; Mn (as $MnSO_4.H_2O$),75; Fe (as $FeSO_4.7H_2O$), 10; Cu (as $CuSO_4$), 1.5; Zn (as $ZnSO_4.H_2O$), 74.

Table 3. Proximate composition of diets[1] (dry weight basis except for moisture content).

Diet	Size	Moisture (% as fed)	Crude protein (%)	Total lipid (%)	Ash (%)	Crude fiber (%)	Nitrogen-free extract[2] (%)	Metabolizable energy[3] (kcal/g)
CTR	# 4	5.6 (6.3)[4]	45.6	16.6	7.5	3.5[5]	26.8	3.67
	2.4mm (3/32")	5.6 (10.1)	45.4	14.7	7.5	3.5	28.9	3.54
MTT-GRT	# 4	9.0 (8.7)	44.7	14.2	8.5	3.2[5]	29.4	3.48
	3mm	8.9 (8.5)	41.3 (42.4)	17.2 (21.2)	9.6	3.2	28.7	3.58
ABY	6/64" granule	12.0	49.4	13.9	11.6	1.3-2.4[5]	22.7-23.8	3.55
	3/32"	11.8	47.2	12.0	10.7	1.2-2.4	27.7-28.9	3.39
SCS	# 4	10.3	51.7	10.5	11.6	7.0[6]	19.2	3.32
	3/32"	9.4	51.5	14.7	10.5	7.0	16.3	3.60
SCT	# 4	10.9	53.4	10.6	12.5	7.0[6]	16.5	3.35
	3/32"	11.0	48.7	9.4	12.6	7.0	22.3	3.15
MTT-MNR	2GR	9.5	47.9	15.4	8.3	3.4[5]	25.0	3.60
	3PT	8.4	47.9	16.5	7.8	3.4	24.4	3.72

[1]All analyses performed in duplicate.

[2]Nitrogen-free extract determined by subtraction of protein, lipid, ash and fiber from 100.0%.

[3]Based on values of Brett and Groves (1979) for estimating caloric value of diet. ie. 4.2 kcal/g protein, 8.0 kcal/g lipid and 1.6 kcal/g carbohydrate.

[4]Values in parentheses represent composition of diets during Experiment 2.

[5]Fiber content of CTR, MTT-GRT, ABY and MTT-MNR estimated from diet formulations and proximate composition of feedstuffs (NRC 1981).

[6]Fiber content of SCS and SCT represent maximum limit of fiber specified on the feed bag.

Table 4. Percent fines removed by prescreening and sizes of feed as fed.

Diet	Size	Pellet diameter (mm)	Pellet length mean (mm)	Pellet length range (mm)	% Removed as fines in prescreening[1]	Through sieve no[2]: / Over sieve no:	Relative percent recovered in screen series performed on prescreened feed 6 / 8	8 / 10	10 / 12	12 / 14	14 / 16	16 / --
CTR	# 4	-	-	-	-		5	34	29	24	4	3
	2.4mm (3/32")	3	4.5	3.5-5.5	-							
MTT-GRT	# 4	-	-	-	0.3		6	31	35	20	6	2
	3MM (3/32")	3	4.3	3-7	0.3							
	3MM (3/32")[3]	3	3.7	2-6	-							
ABY	6/64" granules	-	-	-	1.8		28	41	25	5	1	1
	3/32"	3	4.4	3-7	0.9							
SCS	# 4	-	-	-	1.9		41	42	12	2	2	1
	3/32"	3	4.9	3.5-6	0.8							
SCT	# 4	-	-	-	2.6		56	33	8	2	1	1
	3/32"	3	4.5	3-6	1.6							
MTT-MNR[3]	2GR	-	-	-	1.8		0	33	39	14	10	5
	3PT (3/32")	3	4.0	2-7	0.5							

- Not measured.

[1]Fines are defined as the material passing through a No. 16 sieve (for granular feeds) or through a No. 12 sieve (for pelleted feeds).

[2]Canadian (equivalent to U.S. size) sieve series mesh openings: No. 6 (3.35 mm), No. 8 (2.36 mm), No. 10 (2.00 mm), No. 12 (1.70 mm), No. 14 (1.40 mm) and No. 16 (1.18 mm).

[3]Experiment 2.

Table 5. Performance of Sunndalsora Arctic charr and rainbow trout fed test diets for 14 weeks at 12°C (Experiment 1). Values represent the mean of four replicates with means in each column followed by different superscripts letters being significantly different ($P<0.05$; Duncan's new multiple range test). Regression values for $\log_e$ (ln) weight (g) versus time (days).

Diet	Species	Initial Weight (g)	Weight gain (g)	Feed Intake (g)	Feed Conversion (dry weight feed ÷ wet weight gain)	Slope	Intercept	r^2
CTR	Arctic charr	12.9	40.7^{b}	56.2^{c}	1.41^{b}	0.014	2.58	0.98
CTR	Rainbow trout	13.0	65.4^{a}	72.5^{b}	1.11^{b}	0.018	2.68	0.98
MTT-GRT	Arctic charr	13.0	25.2^{c}	60.5^{bc}	2.60^{a}	0.011	2.58	0.91
MTT-GRT	Rainbow trout	13.1	71.3^{a}	86.6^{a}	1.22^{b}	0.018	2.70	0.96
ANOVA[1]		P>0.4	P<0.001	P<0.001	P<0.001			

[1] Analysis of variance (ANOVA) for a randomized complete block design. General Linear Model - Statistical Analysis System (SAS Institute 1979).

Table 6. Performance of Sunndalsora Arctic charr fed test diets for 20 weeks at 12°C (Experiment 1). Values represent the mean of four replicates with means in each column followed by different superscript letters being significantly different ($P<0.05$; Duncan's new multiple range test). Regression values for $\log_e$ (ln) weight (g) versus time (days).

Diet	Initial weight (g)	Weight gain (g)	Feed intake (g)	Feed conversion (dry weight feed ÷ wet weight gain)	Slope	Intercept	r^2
CTR	12.9	79.4^{a}	104.1	1.35^{b}	0.014	2.58	0.98
MTT-GRT	13.0	50.6^{bc}	105.0	2.19^{a}	0.011	2.58	0.91
ABY	12.9	39.8^{c}	91.3	2.43^{a}	0.010	2.51	0.89
SCS	12.9	65.0^{ab}	119.8	1.93^{ab}	0.013	2.57	0.91
SCT	13.0	64.9^{ab}	114.8	1.81^{ab}	0.013	2.56	0.97
ANOVA[1]	P>0.5	P<0.05	P>0.05	P<0.05			

[1] Analysis of variance (ANOVA) for a randomized complete block design. General Linear Model - Statistical Analysis System (SAS Institute 1979).

Table 7. Performance of Labrador Arctic charr fed test diets for 12 weeks at 12°C (Experiment 2). Values represent the mean of three replicates. Regression values for $\log_e$ (ln) weight (g) vs time (days).

Diet	Initial weight (g)	Weight gain (g)	Feed intake (g)	Feed conversion (dry weight feed ÷ wet weight gain)	Slope	Intercept	r^2
CTR	12.3	59.9	68.6	1.15	0.021	2.52	0.99
MTT-GRT	12.3	52.8	61.5	1.17	0.020	2.52	0.98
MTT-MNR	12.3	63.1	67.6	1.07	0.022	2.51	0.98
ANOVA[1]	P>0.5	P>0.2	P>0.3	P>0.1			

[1] Analysis of variance (ANOVA) for a completely randomized design. General Linear Model - Statistical Analysis System (SAS Institute 1979).

Table 8. Biochemical composition of liver and muscle tissue[1], hepatosomatic index (HSI)[2], visceral fat rating[3] and haematocrit value[4] of Sunndalsora rainbow trout and Arctic charr (Experiment 1). Means in each column followed by different superscript letters are significantly different ($P<0.05$; Duncan's new multiple range test). Level of significance for ANOVA was $P<0.001$ for all parameters, except visceral fat rating ($P>0.05$).

Species	Diet	HSI	Visceral fat rating	Haematocrit	Liver			Muscle				
					Moisture (%)	Total lipid (% wet)	Total lipid (% dry)	Moisture	Total lipid (% wet)	Total lipid (% dry)	Crude protein (% wet)	Crude protein (% dry)
Sunndalsora rainbow trout	CTR	1.25^{de}	1.8	40.5^{a}	72.3^{a}	4.5^{cd}	16.3^{cd}	75.8^{b}	4.7^{ab}	19.2^{a}	17.8^{de}	73.4^{cd}
	MTT-GRT	1.22^{e}	2.1	39.3^{a}	70.2^{a}	5.6^{bcd}	18.8^{bc}	75.5^{b}	5.2^{a}	21.3^{a}	17.3^{e}	70.8^{d}
Sunndalsora Arctic charr	CTR	1.56^{b}	1.7	36.7^{b}	62.0^{b}	15.1^{a}	39.2^{a}	74.8^{b}	4.1^{bc}	16.0^{b}	19.0^{b}	75.6^{bc}
	MTT-GRT	1.77^{a}	1.5	39.2^{a}	63.1^{b}	13.0^{a}	34.7^{a}	76.1^{b}	3.8^{c}	15.9^{b}	18.2^{cd}	76.4^{bc}
	ABY	1.29^{de}	1.0	36.4^{b}	72.6^{a}	4.0^{d}	14.5^{d}	77.8^{a}	1.8^{e}	7.9^{d}	17.9^{d}	80.8^{a}
	SCS	1.45^{bc}	1.5	40.0^{a}	69.5^{a}	5.9^{bc}	19.2^{bc}	75.7^{b}	3.0^{d}	12.5^{c}	18.8^{bc}	77.6^{ab}
	SCT	1.37^{d}	1.1	38.9^{a}	69.3^{a}	7.5^{b}	23.2^{b}	74.6^{b}	3.5^{cd}	13.6^{c}	19.6^{a}	80.0^{ab}

[1] Total of 12 analyses per treatment.
[2] HSI = liver weight(g) ÷ body weight(g) x 100. Total of 24 measurements per treatment.
[3] Rating of 0 to 3.
[4] Total of 24 measurements per treatment.

Table 9. Biochemical composition of liver and muscle tissue[1], hepatosomatic index[2] (HSI), visceral fat rating[3] and haematocrit value[2] of Labrador Arctic charr (Experiment 2). Level of significance for ANOVA was P>0.1 for all parameters.

Species	Diet	HSI	Visceral fat rating	Haematocrit	Liver			Muscle				
					Moisture (%)	Total lipid (% wet)	Total lipid (% dry)	Moisture	Total lipid (% wet)	Total lipid (% dry)	Crude protein (% wet)	Crude protein (% dry)
Labrador Arctic charr	CTR	1.78	1.6	44.8	63.0	13.5	36.1	75.3	4.5	18.1	17.4	70.5
	MTT-GRT	1.88	1.4	43.9	63.5	12.9	35.4	75.7	3.8	15.7	17.4	71.5
	MTT-MNR	1.97	1.9	43.5	61.2	16.7	42.6	74.9	4.4	17.6	17.7	70.4

[1] Total of 9 analyses.
[2] Total of 18 measurements per treatment.
[3] Rating from 0 to 3.

Table 10. Water quality parameters during Experiments 1 and 2.

	Experiment 1		Experiment 2	
	Range	Mean ± SE	Range	Mean ± SE
(NH_4+NH_3)-N (µg/L)	50 - 348	175 ± 32	33 - 312	129 ± 35
NO_2 - N (µg/L)	2 - 79	16 ± 8	10 - 75	26 ± 7
NO_3 - N (µg/L)	190 - 1925	894 ± 207	224 - 1520	900 ± 161
pH	7.7 - 8.1	7.9 ± 0.04	7.8 - 8.3	8.0 ± 0.08
Temperature (°C)	10.0 - 13.0	12.0 ± 0.2	11.9 - 12.0	12.0 ± 0.01
D.O. (mg/L)	7.8 - 10.8	9.2 ± 0.5	7.5 - 11.3	9.4 ± 0.6
Number weeks sampled	9		10	

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